

Biasing and the search for primordial non-Gaussianity beyond the local type

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Surveys for Cosmology

Many new surveys to come online: LSST, WFIRST, EUCLID,...

What's causing the accelerated expansion of the Universe ?

Cosmological constant?

Dark Energy?

Modifications of General Relativity?

And more

Equivalence Principle (EP)

→ Do all objects fall the same way?

Cornerstone of GR

Initial conditions

→ Is the distribution initially Gaussian?

Prediction of simplest inflation models

Non Gaussianity and Inflation

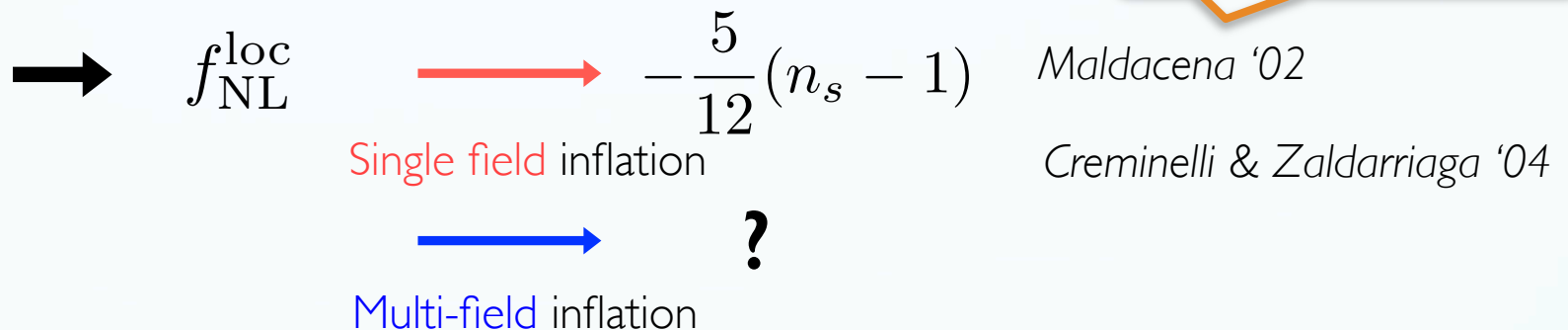
Scale dependent bias

Equilateral non-Gaussianity

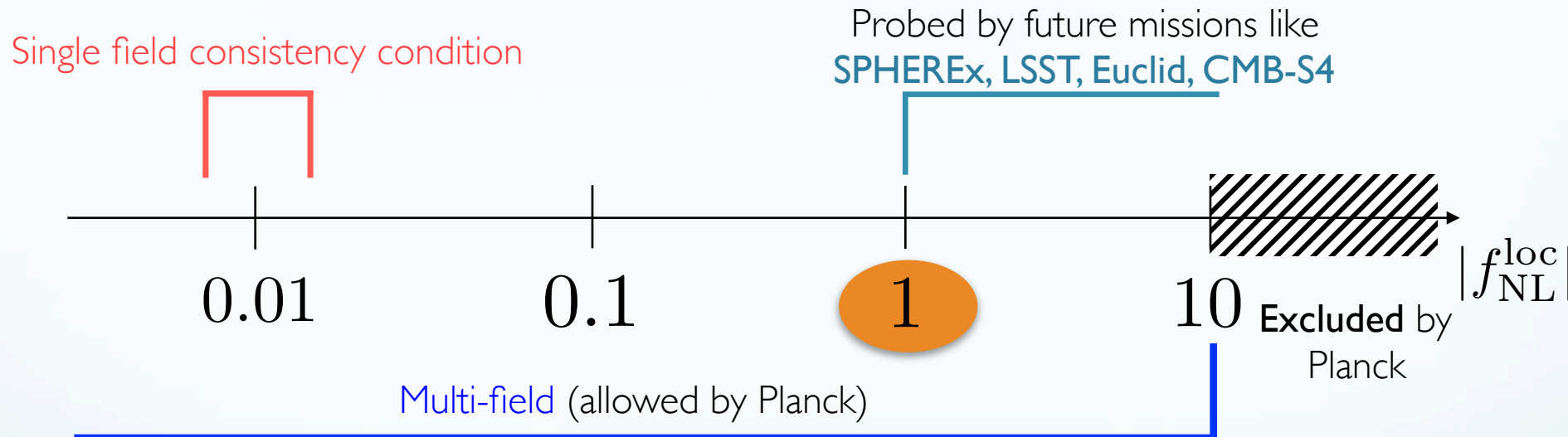
Why study non-Gaussianity?

$$\Phi = \Phi_G + f_{\text{NL}}^{\text{Loc}}(\Phi_G^2 - \langle \Phi_G \rangle^2)$$

Consistency relation



Why study non-Gaussianity?



$$\text{Prob}(|f_{\text{NL}}^{\text{Loc}}| > 1) \gtrsim 50\%^* \quad \text{with de Putter and Doré arXiv:1612.05248}$$

* : 2-field models with **spectator** field

Measuring PNG from surveys

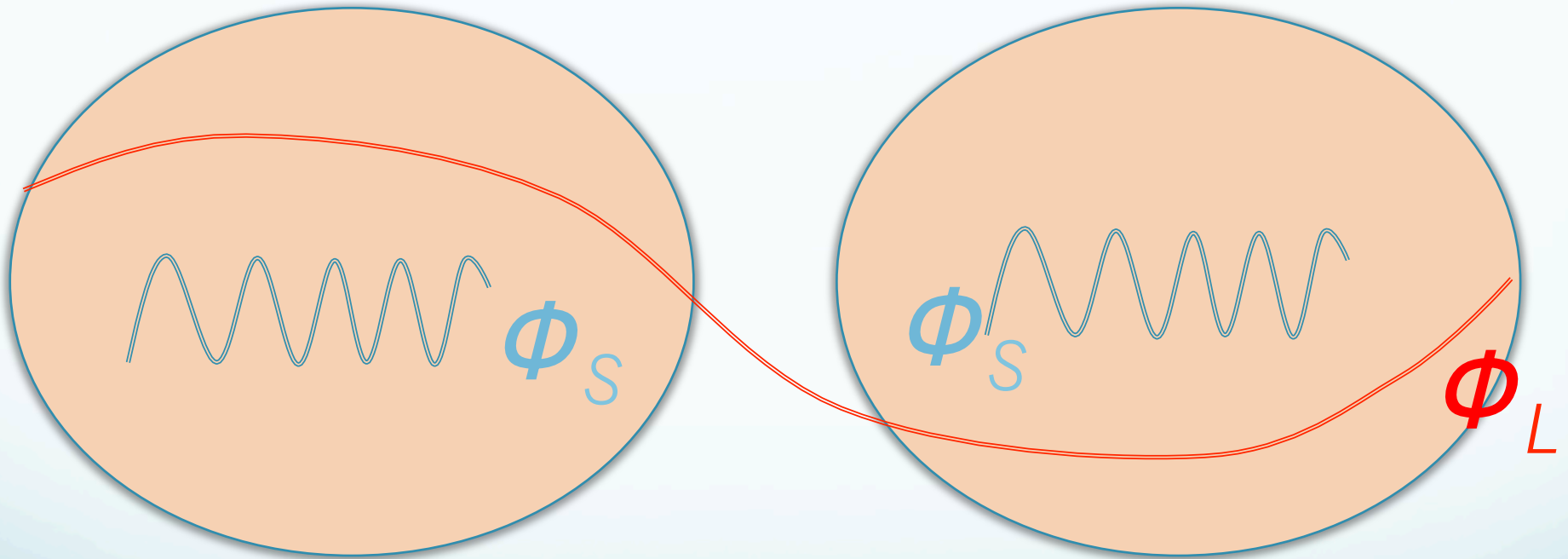
✧ CMB: Bispectrum

$$\sigma(f_{\text{NL}}^{\text{Loc}}) \sim 5$$

✧ Galaxy surveys: scale-dependent bias

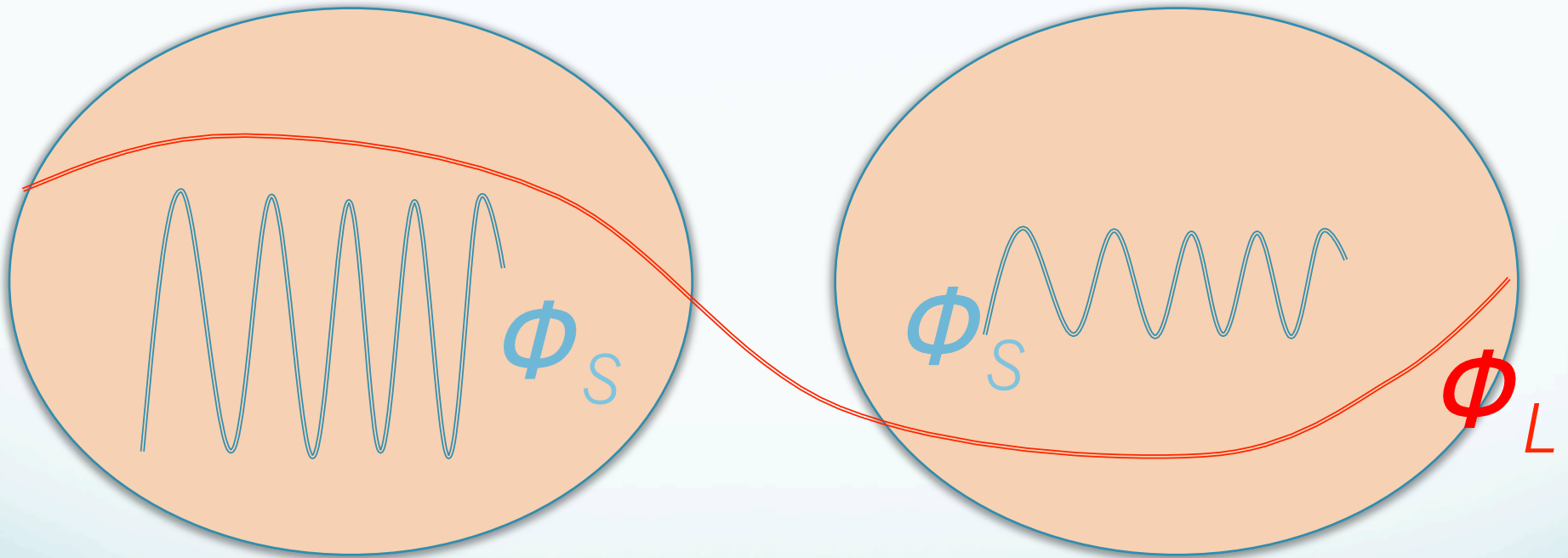
Scale-dependent bias

Single field inflation



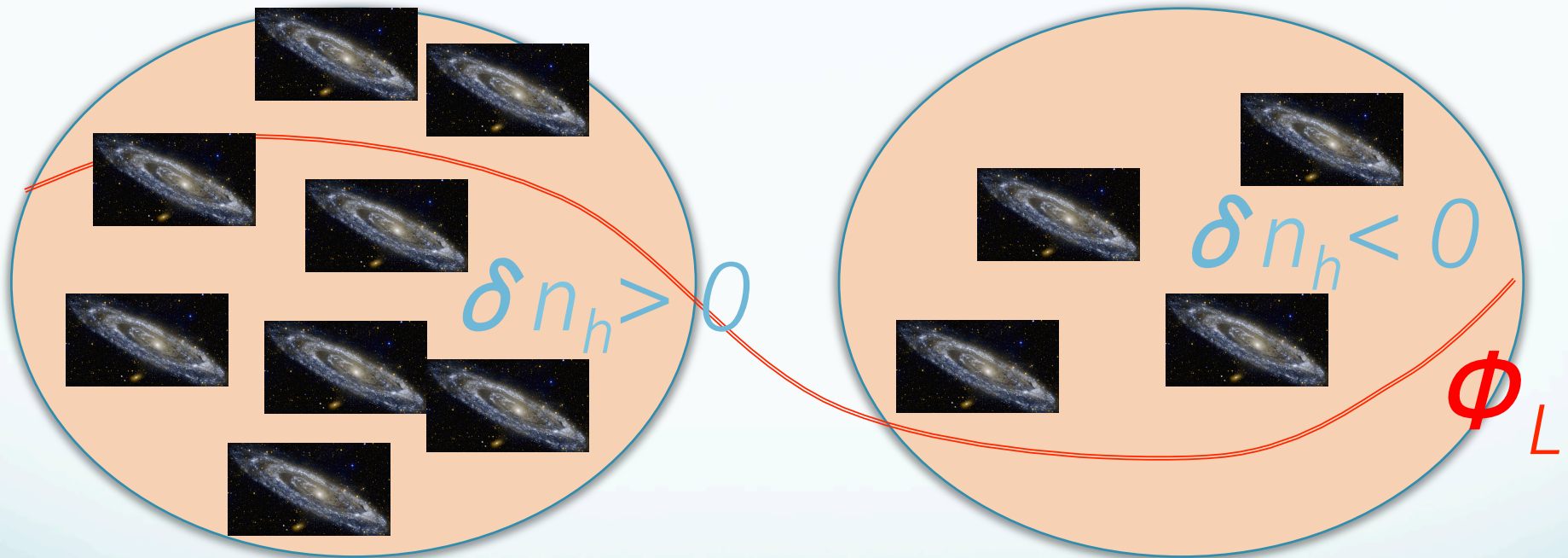
Scale-dependent bias

Multi-field inflation



Scale-dependent bias

Multi-field inflation



Scale-dependent bias

Scale-dependent bias

✧ Local PNG

$$\mathcal{M}(q) \equiv \frac{2q^2 T(q) D(z)}{3\Omega_m H_0^2}$$

$$b_{\text{NG}}(q) = 2 f_{\text{NL}}^{\text{Loc}} (b_\delta - 1) \delta_c \mathcal{M}^{-1}(q) \sim \frac{1}{q^2 T(q)}$$

✧ Equilateral PNG

Typical size of halos

$$b_{\text{NG}}(q) = 6 f_{\text{NL}}^{\text{Eq}} (b_\delta - 1) \delta_c (q R_*)^2 \mathcal{M}^{-1}(q) \sim \frac{1}{T(q)}$$

Biasing and PNG

with de Putter, Green and Doré arXiv:1612.06366

✧ Generalized model of bias *McDonald & Roy '09, Assassi et al '15*

δ^2

$$\delta_h = b_\delta \delta + b_{\text{NG}}(q) \delta + F_{\text{nonlocal}}[\nabla^2 \delta] + F_{\text{nonlinear}}[\delta]$$

$$\left[b_{q^2} (qR_*)^2 + b_{q^4} (qR_*)^4 \right] \delta$$

Seen in simulations *Chan et al '12, Baldauf et al '12*

✧ Evolution or PNG?

$$T(q) \sim 1 + T_1 q^2 + T_2 q^4$$

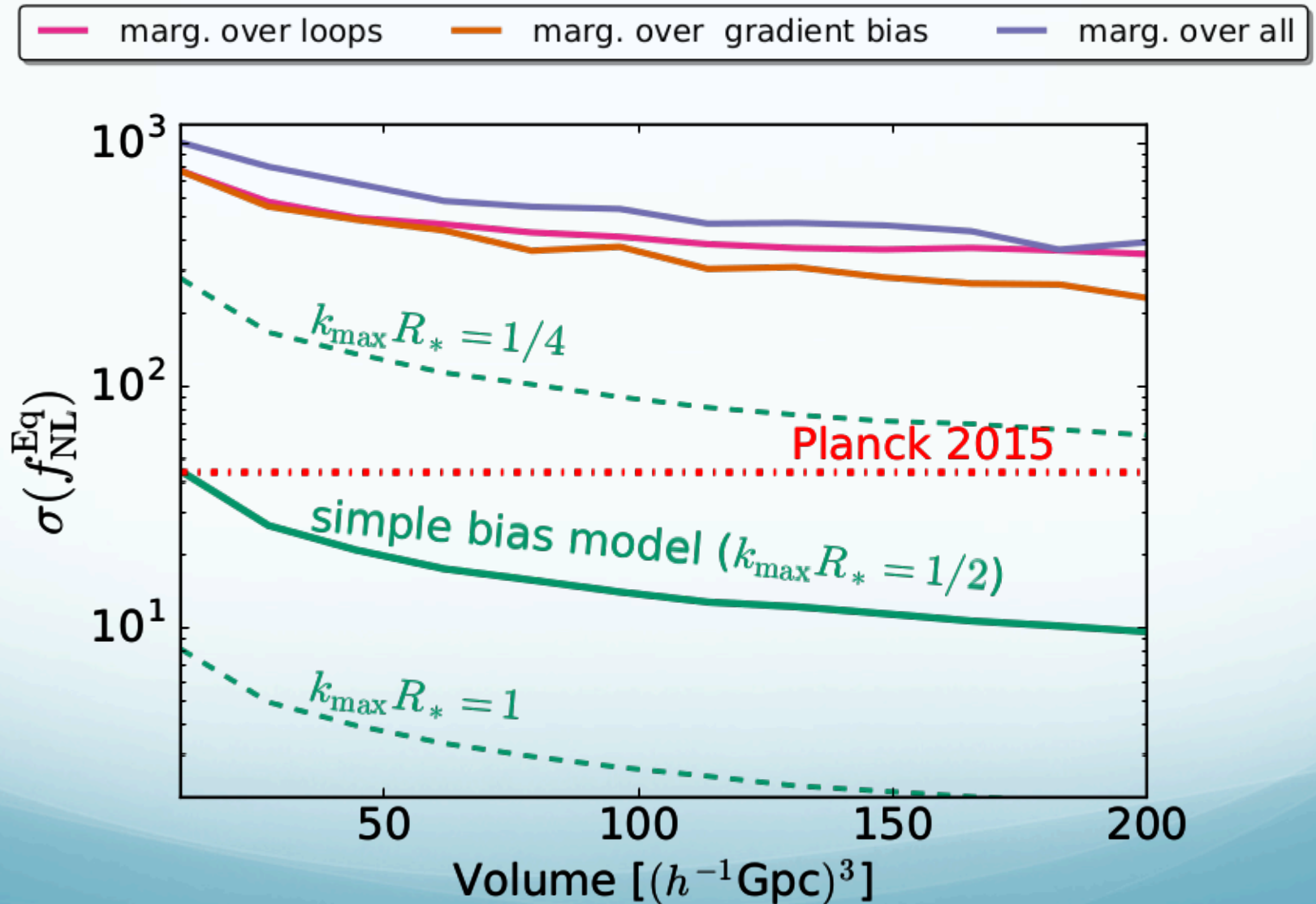
$$b_{\text{NG}}^{\text{Loc}} \sim q^{-2} \quad \checkmark$$

$$b_{\text{NG}}^{\text{Eq}} \sim c + c_1 q^2 + \dots \quad ?$$

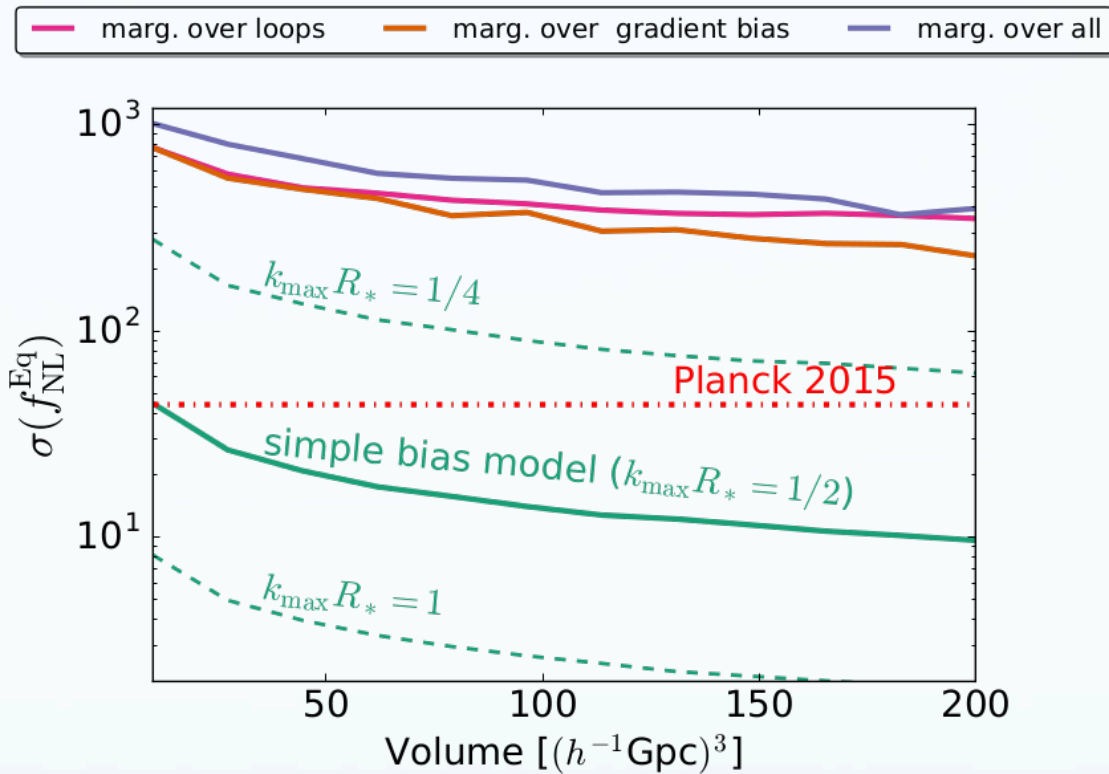


Consistency relation **not** broken

Equilateral PNG and bias



Equilateral PNG and bias

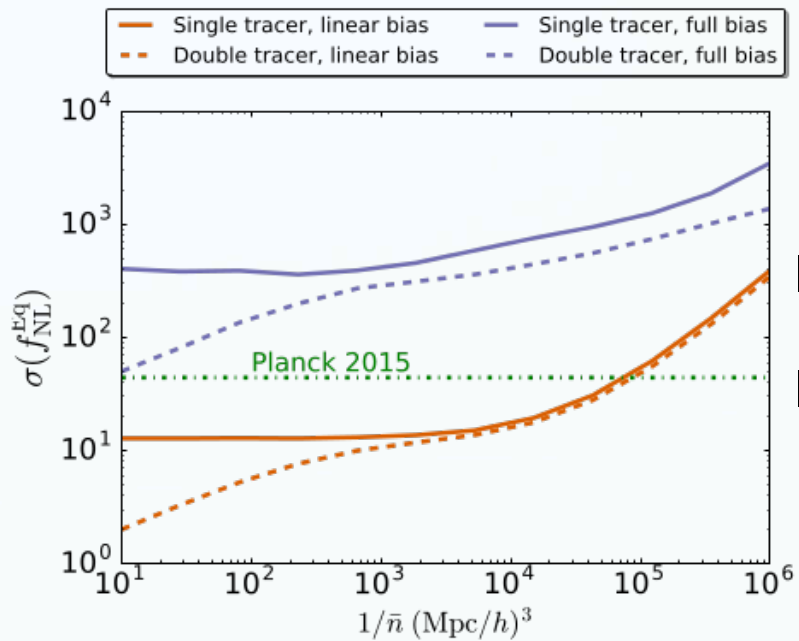
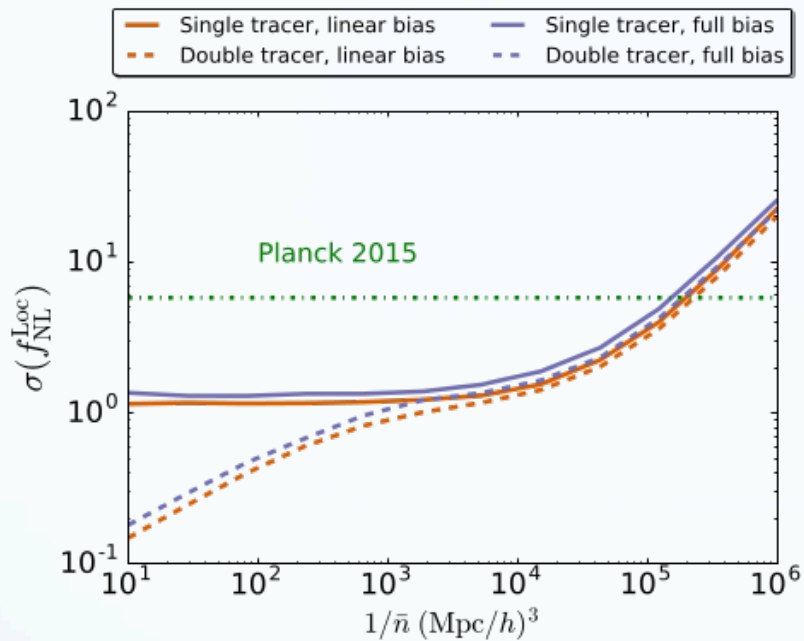


What is helping us

$$F_{\text{nonlocal}}[\nabla^2 \delta] \quad \longrightarrow \quad R_*^{-1} > k_{\text{max}}$$

$$T(q) \quad \longrightarrow \quad k_{\text{eq}} \sim 10^{-2} h/\text{Mpc} < k_{\text{max}} \sim 10^{-1} h/\text{Mpc}$$

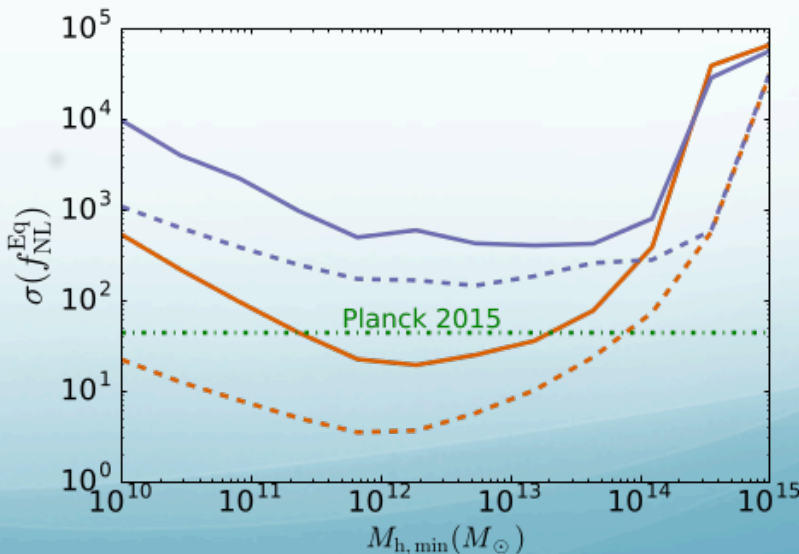
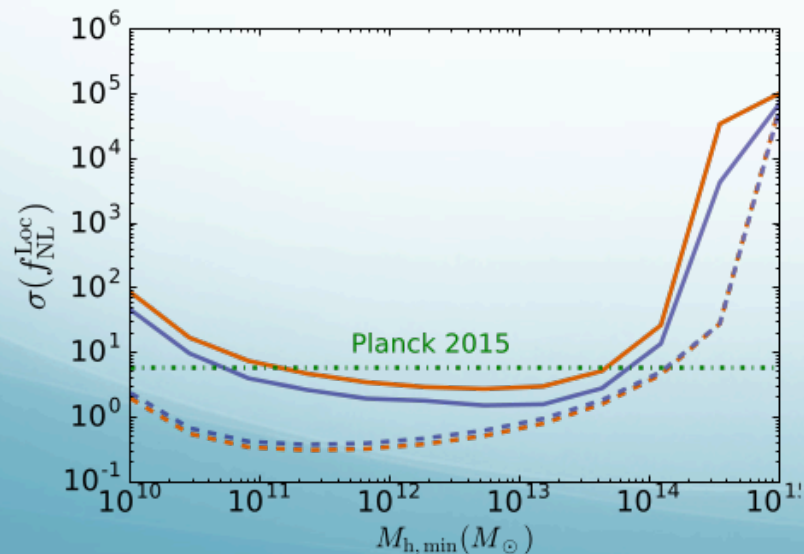
Beating cosmic variance



Tracers

I: galaxy

II: galaxy



I: galaxy

II: DM

Conclusions

Broken in multi-field inflation, with $f_{\text{NL}}^{\text{Loc}} \sim 1$ for spectator fields

Equilateral PNG is degenerate with evolution

Bispectrum more appropriate for PNG beyond local